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OPTIMAL TRAJECTORY DESIGN BY ADAM UNDER STOCHASTIC DISTURBING ACCELERATION

Abstract

The Gateway is expected to enable further deep space exploration and to increase the demand for trajectory design of a spacecraft. However, trajectory design is difficult in the vicinity of the Moon because the dynamics is complex and highly nonlinear. Moreover, trajectories in actual missions are designed under various uncertainties such as disturbances and state uncertainties.

There are two main methods for trajectory optimization problems: direct method and indirect method. The direct method is widely used in trajectory design which converts trajectory optimization problems into nonlinear programming problems. However, its disadvantages are to be highly affected by initial conditions and computationally expensive. In addition, it is difficult to find the solution under stochastic disturbances and/or state uncertainties.

To overcome the disadvantages of the direct method, we propose to apply the adaptive moment estimation (Adam) to trajectory optimization. Adam, a first-order gradient-based optimization algorithm, utilizes the first and second moments of the gradients to efficiently solve an optimization problem with complex models. The advantages of Adam lie in its ability to avoid local minima and robustness against noise. Adam is often used in deep learning and machine learning as stochastic gradient decent (SGD), a method that replaces the actual gradients with stochastically estimated ones. However, Adam is rarely used in any optimization other than SGD without any tangible reasons and has never been applied in trajectory optimization. Then, in trajectory optimization with many local minima, it is expected that Adam's characteristic of avoiding local minima can be taken advantage of and that Adam's robustness against noise will help to design robust trajectories which are maintained under disturbances and associated errors.

This paper considers an optimal transfer trajectory problem between different halo orbits in the Earth-Moon circular restricted three-body problem for impulsive thrust and continuous low-thrust. We show how the trajectory optimization problem with various constraints is solved by using Adam. Then, Monte Carlo simulation validates that the proposed algorithm can find the optimal solution regardless of the initial values. Moreover, it is demonstrated that the proposed Adam-based optimization method is superior to the sequential quadratic programming (SQP) under the presence of external stochastic disturbances, and the robustness of the optimal transfer trajectory is investigated. The characteristics of trajectory optimization based on Adam is discussed for future applications.